

PHY 101: GENERAL PHYSICS I

2018/2019 ACADEMIC SESSION

TOPIC: CONSERVATION LAWS

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Conservation laws also called laws of conservation in physics contain several principles that state that certain physical properties (i.e., measurable quantities) do not change in the course of time within an isolated physical system. In classical physics, laws of this type govern **energy**, **momentum**, **angular momentum**, **mass**, and **electric charge**. In particle physics, other conservation laws apply to properties of subatomic particles that are invariant during interactions. An important function of conservation laws is that they **make it possible to predict the macroscopic behavior of a system without having to consider the microscopic details of the course of a physical process or chemical reaction**.

Conservation of Energy

Conservation of energy states that in an isolated system, the sum of all forms of energy remains constant. In other words, energy can be neither created nor destroyed, although it can be changed from one form (mechanical, kinetic, chemical, etc.) into another. For example, a falling body has a constant amount of energy, but the form of the energy changes from potential to kinetic.

Conservation of Linear Momentum

MOMENTUM

The product of a particle's mass and velocity is called the (linear) **momentum** of the particle:

$$\vec{p} = m\vec{v}$$

Notes:  $\vec{p}$ and $\vec{v}$ have the same direction.

 $\vec{p}$ is more usefully resolved into...

$$p_x = mv_x \quad \text{and} \quad p_y = mv_y$$

 **Units:** [kg m/s]

Newton II reformulated:

$$\vec{F} = m\vec{a} = m \frac{d\vec{v}}{dt} = \frac{d(m\vec{v})}{dt} = \frac{d\vec{p}}{dt}$$

i.e. Force is the rate of change of momentum.

Conservation of linear momentum expresses the fact that a body or system of bodies in motion retains its total momentum, unless an external force is applied to it. In an isolated system (such as the universe), there are no external forces, so momentum is always conserved. Because momentum is conserved, its components in any direction will also be conserved. Application of the law of conservation of momentum is important in the solution of collision problems. Also, the operation of rockets exemplifies the conservation of momentum: the increased forward momentum of the rocket is equal but opposite in sign to the momentum of the ejected exhaust gases.

Conservation of Angular Momentum

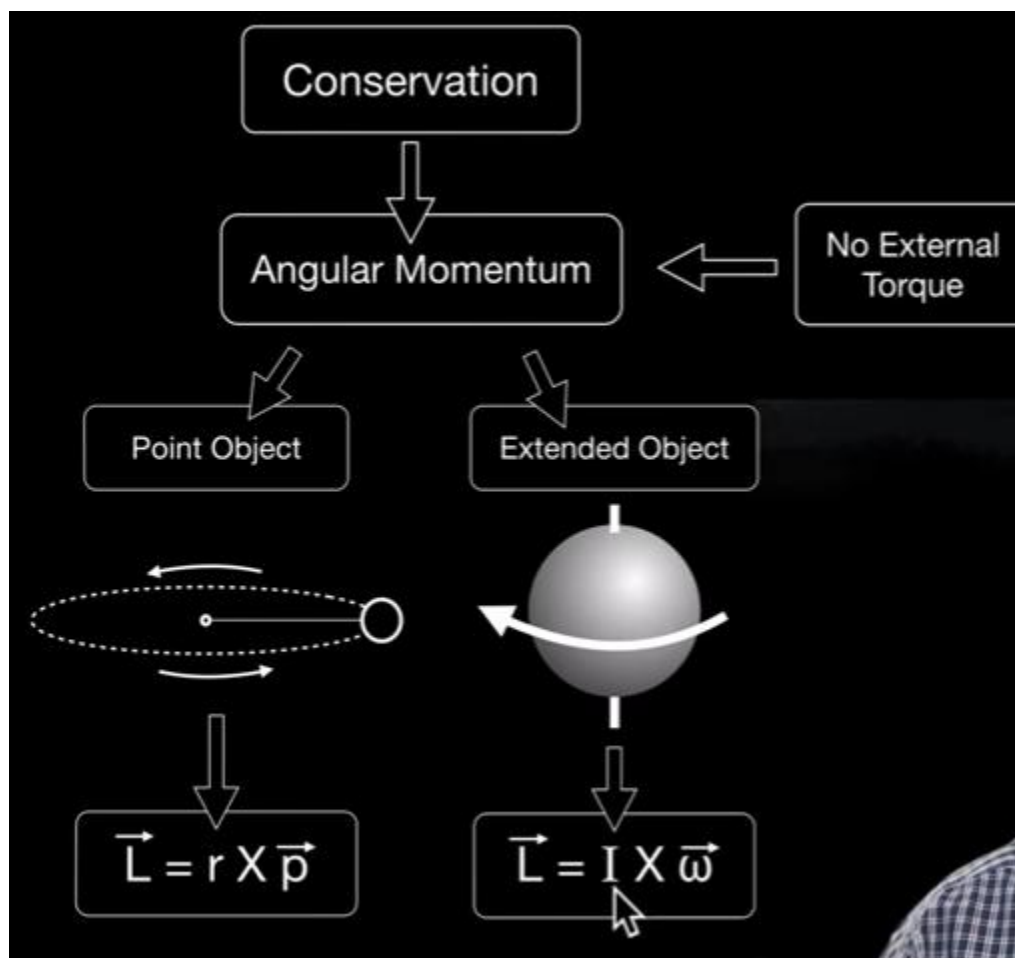


Figure 1: conservation of angular momentum in point and extended objects.

L = Angular momentum (kgm^2/s)

r = radius from the center (m)

P = linear momentum (kgm/s)

I = moment of inertia (kgm^2 how much of the material we have and how much it is spread out from the center).

ω = angular velocity (rads^{-1}).

Conservation of angular momentum of rotating bodies is analogous to the conservation of linear momentum. Angular momentum is a vector quantity whose conservation expresses the law that a body or system that is rotating continues to rotate at the same rate unless a twisting force, called a torque, is applied to it. The angular momentum of each bit of matter consists of the product of its mass, its distance from the axis of rotation, and the component of its velocity perpendicular to the line from the axis. The illustration is given in figure 1 above.

Conservation of Mass

According to law of conservation of mass, processes that change the physical or chemical properties of substances within an isolated system (such as conversion of a liquid to a gas) leave the total mass unchanged. I.e. matter can be neither created nor destroyed. In nuclear reactions, the conversion of rest mass into other forms of mass-energy is so small that, to a high degree of precision, rest mass may be thought of as conserved.

Conservation of Charge

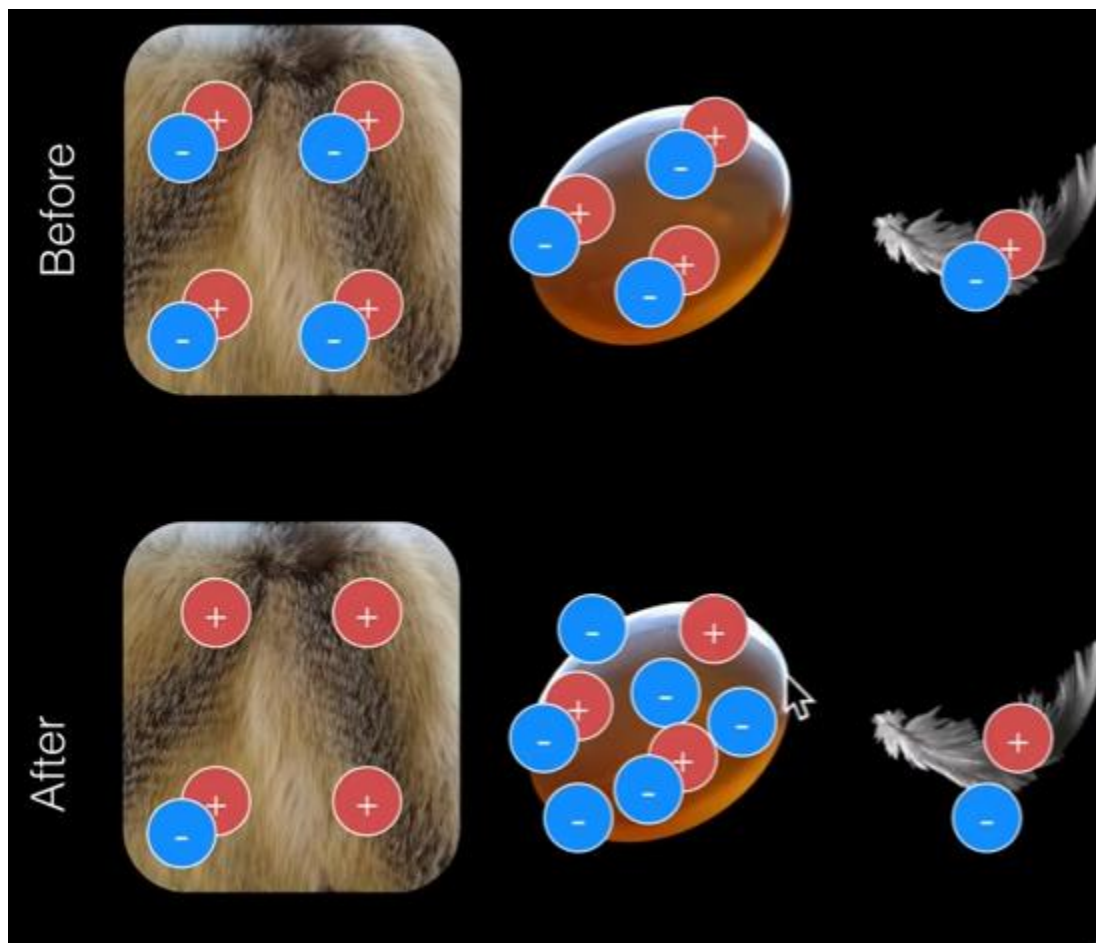


Figure 2: conservation of charge.

Conservation of charge states that the total amount of electric charge in a system does not change with time. At a subatomic level, charged particles can be created, but always in pairs with equal positive and negative charge so that the total amount of charge always remains constant. The illustration of charge conservation is given in figure 2 above.

Summary

The laws of conservation of energy, momentum, angular momentum, charge and mass are all derived from classical mechanics. Nevertheless, all remain true in quantum mechanics and relativistic mechanics, which have replaced classical mechanics as the most fundamental of all laws. In the deepest sense, conservation laws express the facts, respectively, that physics does not change with passing time, with displacement in space, or with rotation in space.

Practice Questions

1. What do we call a measurement of an object's ability to keep spinning?
2. **For angular momentum to be conserved what must be true about the net torque of the system?**
3. **If angular momentum is conserved what must be true about an object's initial angular momentum and final angular momentum?**
4. What is conserved within any system?